Calculating Energy Savings of Cool Roofs

Welcome to the Webinar! We will start at 11:30 AM Eastern Standard Time

Be sure that you are also dialed into the telephone conference call:

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There will be a Q&A session at the end. Questions will be submitted electronically and answered verbally. Submit your questions by selecting "Q&A" on the menu at the top, click in the top box, type your question and click "Ask."

Today's Speakers

Marc LaFrance is the Manager for Building Envelope and Windows R&D programs at the U.S. Department of Energy (DOE) Building Technologies Program. In this role, Mr. LaFrance leads development of the next generation of highly insulated windows, dynamic windows, attic/roof systems, high-R walls with thermal mass effects (phase change material), cool roofs, and the next generation of materials development. He is a Certified Energy Manager and a Certified Sustainable Development Professional by the Association of Energy Engineers.

William Miller, Ph.D., is Program Manager for the Energy and Transportation Sciences Division of the Oak Ridge National Laboratory. Dr. Miller has 30 years of experience in vapor compression refrigeration systems, absorption heat and mass transfer and building science technologies, and is currently involved in several cool roof research projects. These include a PIER-funded cool roof study; investigating sub-tile venting for the Tile Roof Institute and the Metal Construction Association; researching the impacts of low-emittance roofs; and quantifying the energy savings for highly reflective roof products in different geographic regions of the United States.

Joe Huang is President of White Box Technologies, which specializes in building energy design and analysis. A former employee of Lawrence Berkeley National Laboratory, Mr. Huang has 30 years of experience in building energy simulations, beginning with the use and maintenance of the DOE-2 program, and later participated in the development of EnergyPlus. His work includes evaluating building energy efficiency and sustainable design, supporting national, state, and nongovernmental organizations in developing building energy standards and ratings, and providing technical evaluation of policy programs.

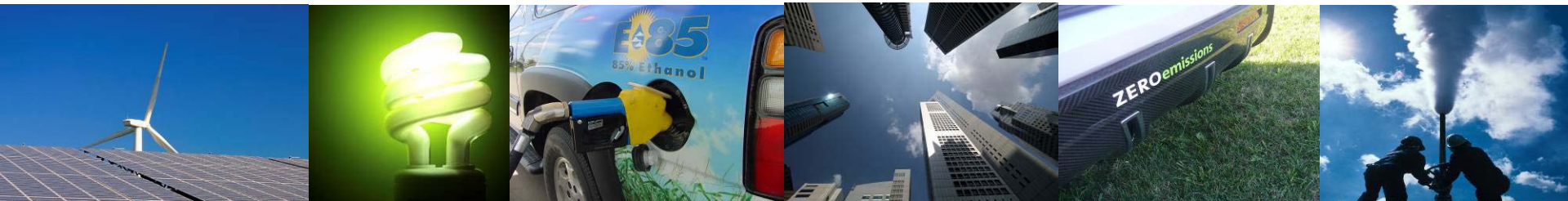
Joshua New, Ph.D., is a computer scientist with Oak Ridge National Laboratory. Dr. New was instrumental in the design and implementation of the Roof Savings Calculator**.** His experience includes graduate research assistantships at both the University of Tennessee and Jacksonville State University, research internships with ORNL, several ORNL/UT collaborative projects and development of special-purpose computer systems for Vital Images and Ft. McClellan. He has 7+ peer-reviewed publications and is an active member of IEEE and ACM.

Envelope Research Program Overview and Cool Roof Update

Advanced Roof Calculator Webinar

22 April 2010

Marc LaFrance
Technology Development Manager
Building Technologies Program
Office of Energy Efficiency and Renewable Energy



EERE Technology Portfolio

Electric Power Generation

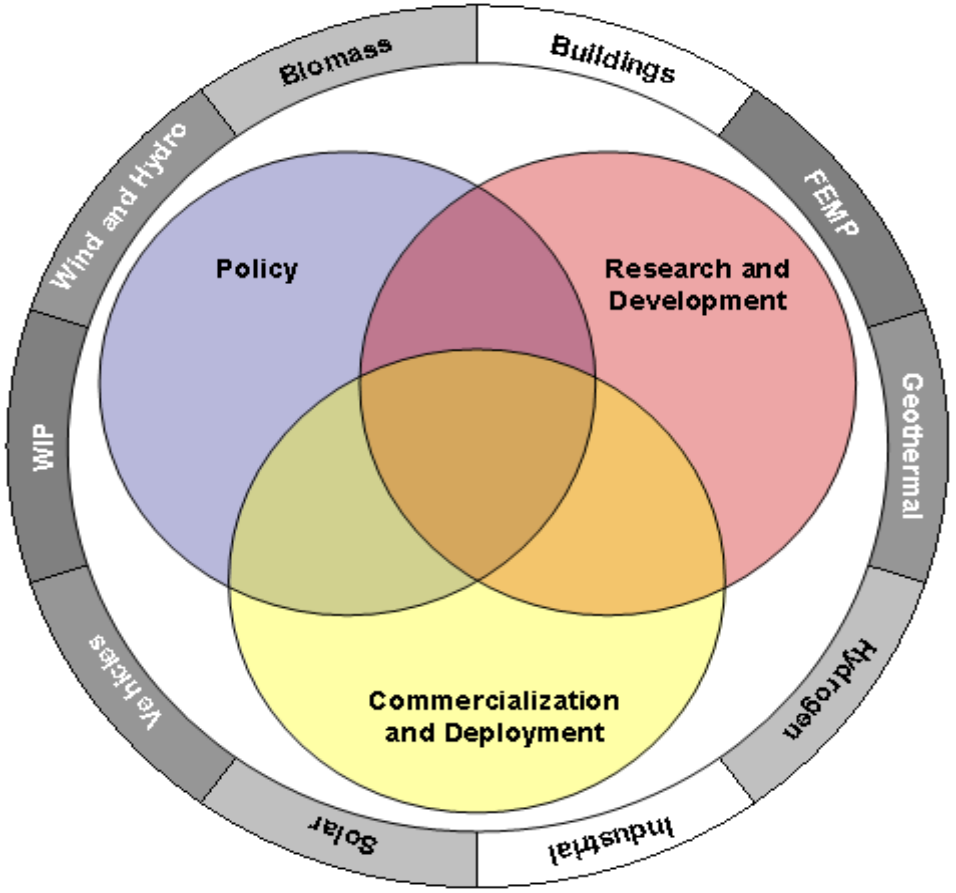
- Geothermal
- Solar
- Wind
- Hydropower & Advanced Water Power

Advanced Transportation

- Biomass
- Fuel Cells
- Advanced Vehicles

Energy Efficiency

- Buildings
- Industrial
- Federal Energy Management
- Weatherization and Intergovernmental

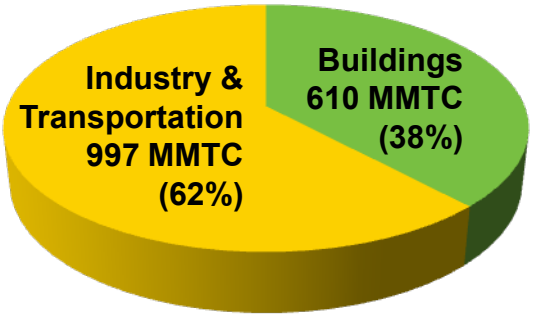


Mission Statement

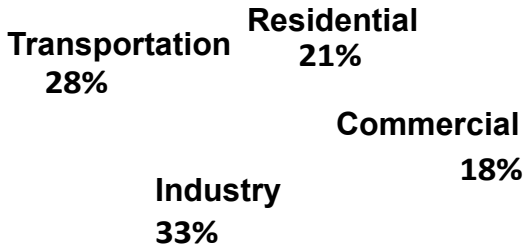
To develop cost competitive technology, facilitate commercialization and deployment to the marketplace

US Building Energy Use and Carbon Emissions

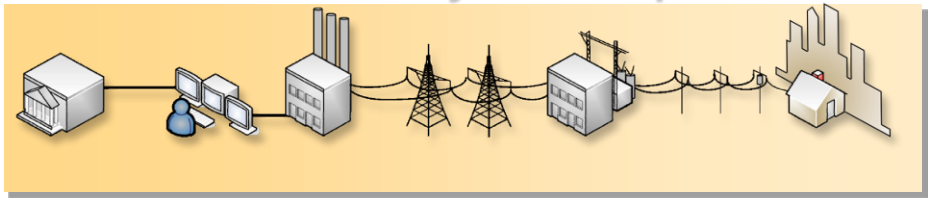
38% of U.S. Carbon Emissions



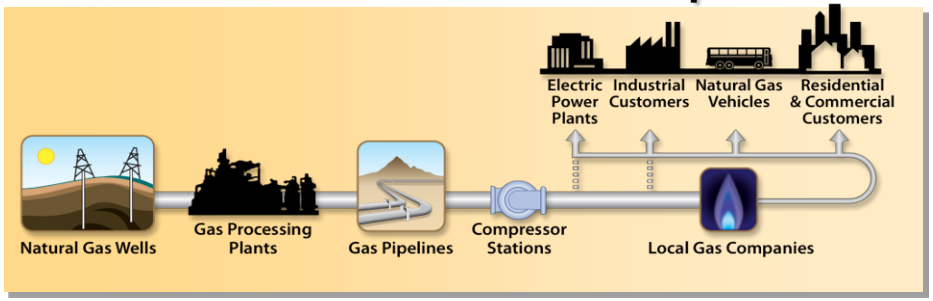
39% of U.S. Primary Energy Consumption



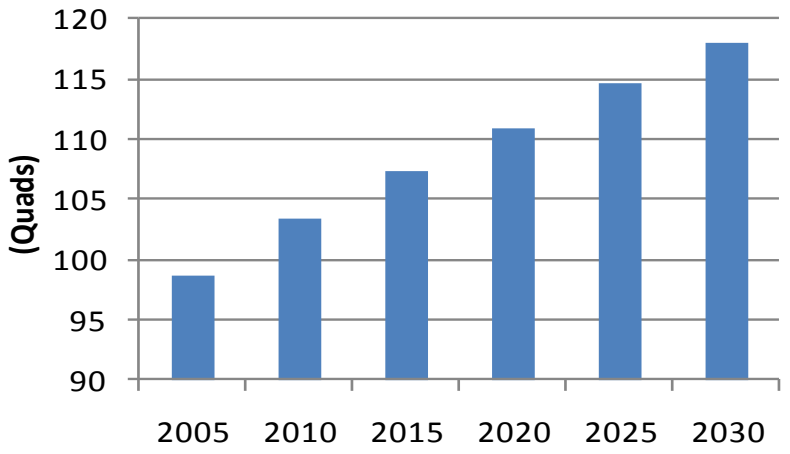
72% of U.S. Electricity Consumption



54% of U.S. Natural Gas Consumption

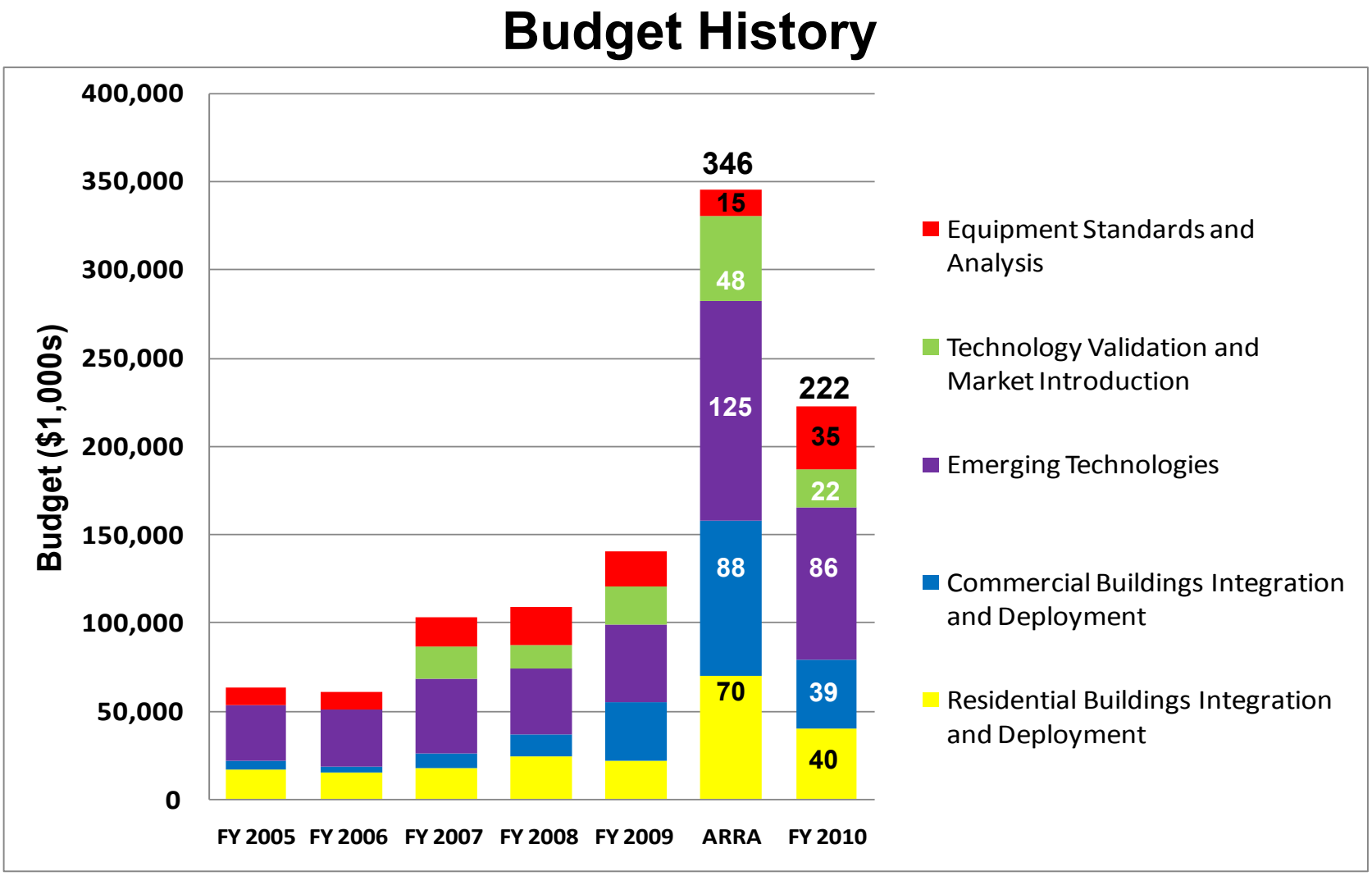


Total U.S. Energy Consumption



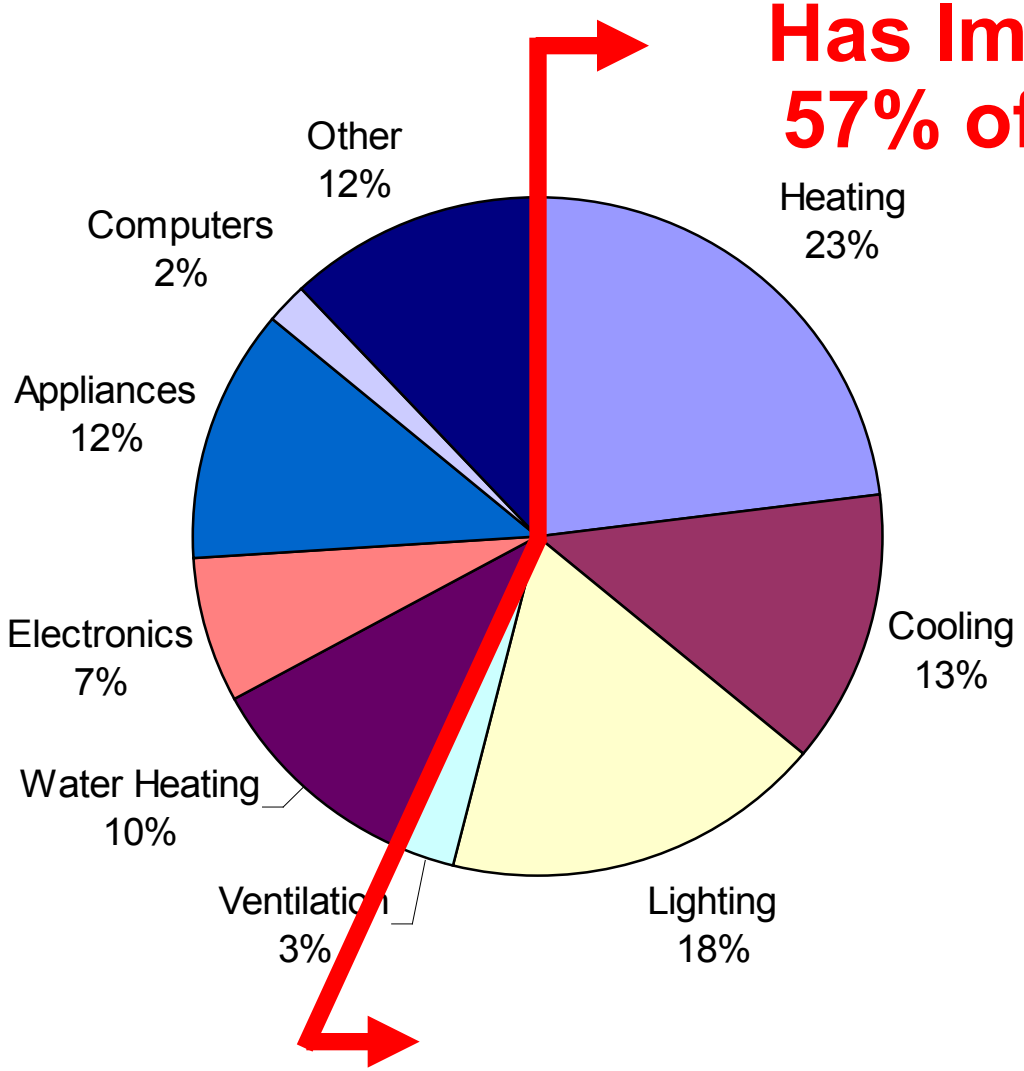
Sources: BED 2009; AEO 2010

BTP's funding has increased dramatically over the past 5 years.



Source: U.S. DOE

Building Consumption – Envelope Relationship



Total Building Envelope and Window R&D Budget

	Administration Budget Request	Enacted Appropriations
FY04	5.1M	8.2M
FY05	5.0M Windows 0 Envelope	5.8M Windows 2.8M Envelope
FY06	5.0M Windows 0 Envelope	*3.8M Windows (*earmarks) 2.9M Envelope
FY07 & FY08	4.7M Windows 2.4M Envelopes	4.7M Windows 2.4M Envelope
FY09	5.2M Windows 3.4M Envelopes	5.5 Windows 4.5 Envelope
FY 10	10.5M Windows 5.5M Envelope	**Core** **ARRA** **10.5M Windows** **~ 20M** **5.5M Envelope** **~15M**
FY 11	10.5M Windows **8.0M Envelope**	**TBD** **(FY11 Request adds 2.5M for Cool Roofs)**

Building Technologies Goal

Net-Zero Energy Buildings by 2025

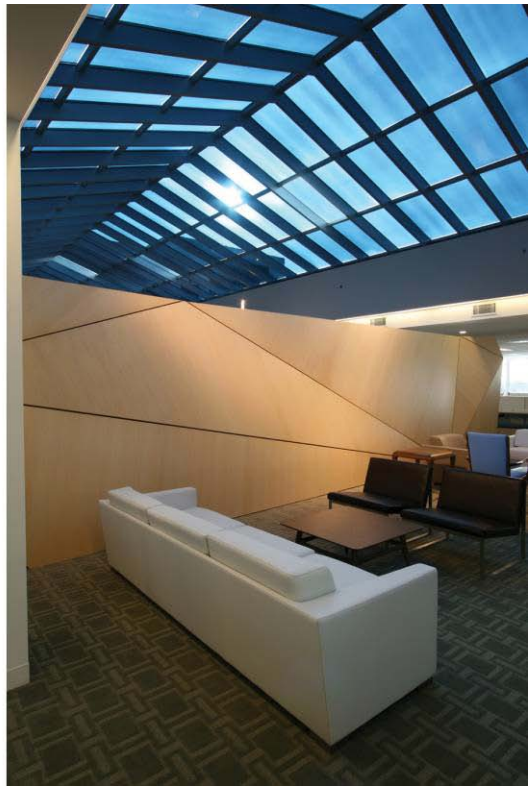
Net-Zero Energy Homes by 2020

Low incremental cost.

Next Generation of Windows

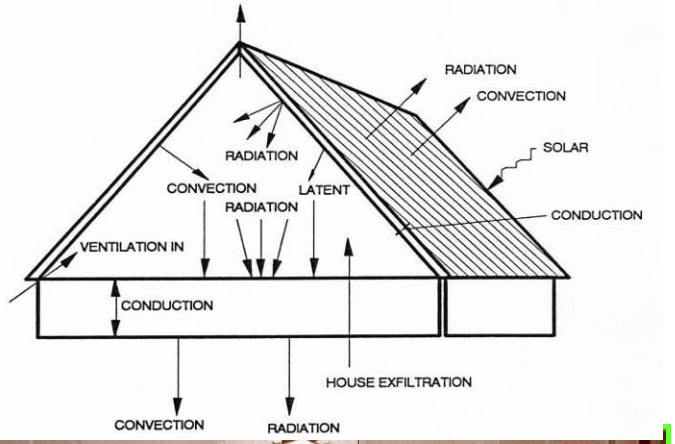
- Highly Insulating
  - Goal U value 0.10 (SI U value 0.56)
  - Possible vacuum glazings
- Dynamic solar control
  - Passive heating
  - Dramatic peak cooling reduction
  - Market ready, prices will drop with more investment

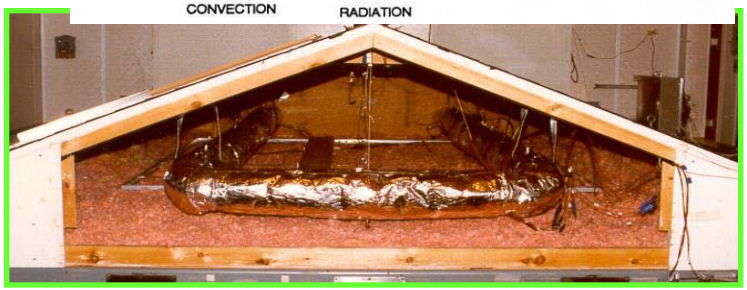
Prototype – Concept Window
(Highly Insulating and Dynamic
U Value 0.18 (SI U value 1.0)
SHGC 0.04 – 0.34)
Low cost unsealed center lite



Thermal Envelope R&D

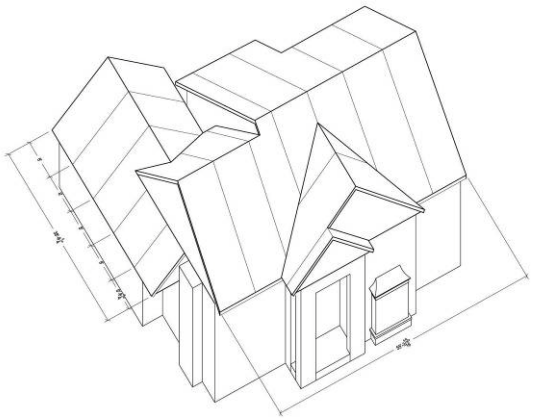
- Advanced walls to reach R20 in 3.5” cavity, exterior insulation systems, R30 total wall
- Next Generation of Attic/Roof System to save 50 Percent Energy
- New Material Development
  - 100 R&D Award in 2009 for phase change insulation
  - Higher performing foams and aerogels
  - Dynamic membranes



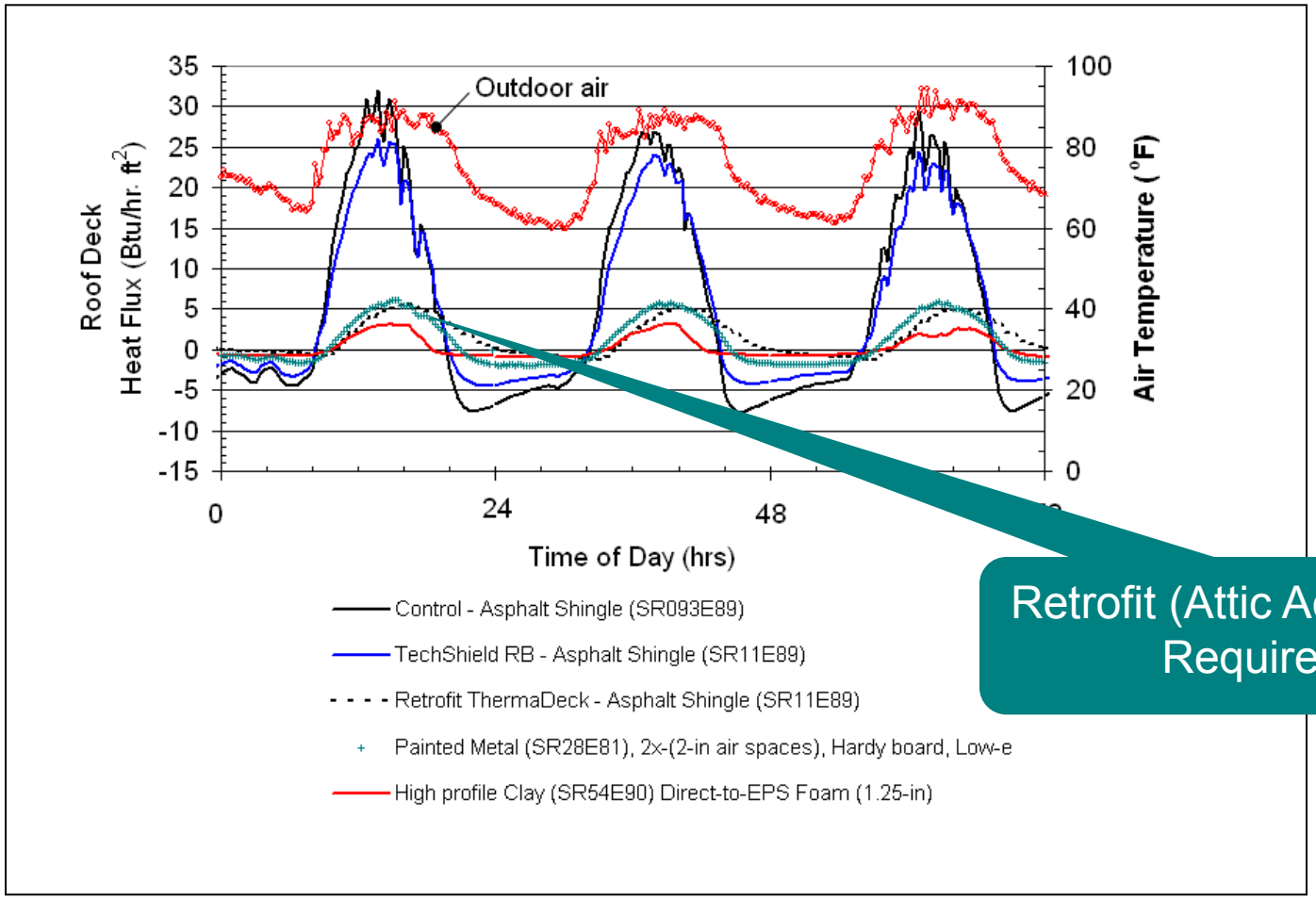


Next Generation of Roofing/Attics

- Integrated solutions for building type and climate
- Key elements to develop and integrate
  - Cool Roofs (lighter colors and near-infrared (NIR) reflective pigments)
  - Thermal Mass
  - Above Deck Ventilation
  - Radiant Barriers
  - Location and Higher Performing Insulations



Cost-Effective New $2/ft² Retrofit Roof System for Hot Climate



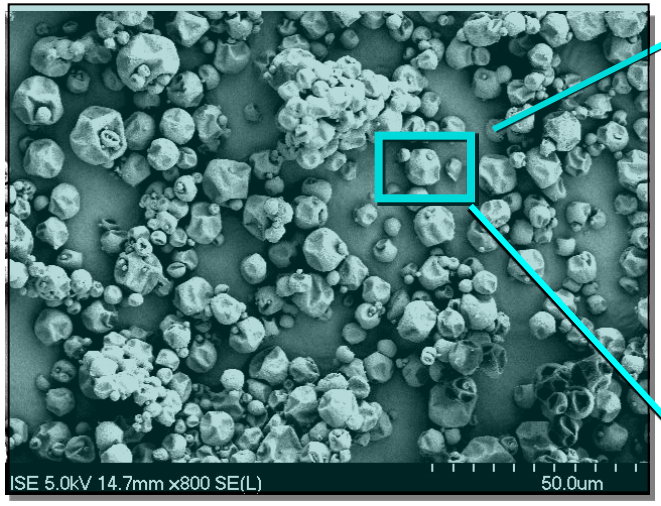
Retrofit (Attic Access Not Required)

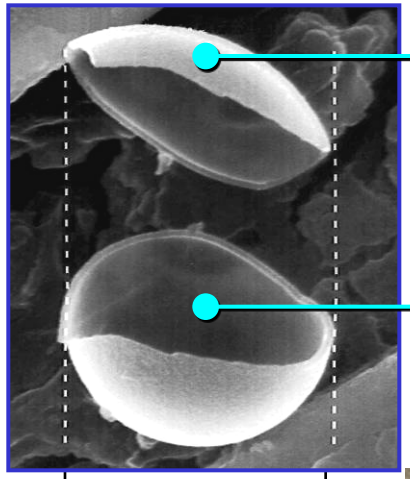
- Continuing Mixed and Cold Climate Research

2009 R&D 100 Award

Low-Flammable PCM-Enhanced Cellulose Insulation – Roof Application

Recycled Paper Waste





Polymer coating

Bio-Based PCM
Fp: ca. 80F
Δ H: 170 J/g

5 - 25 µm

ADVANCED FIBER TECHNOLOGY

microtek LABORATORIES, INC.

OAK RIDGE National Laboratory

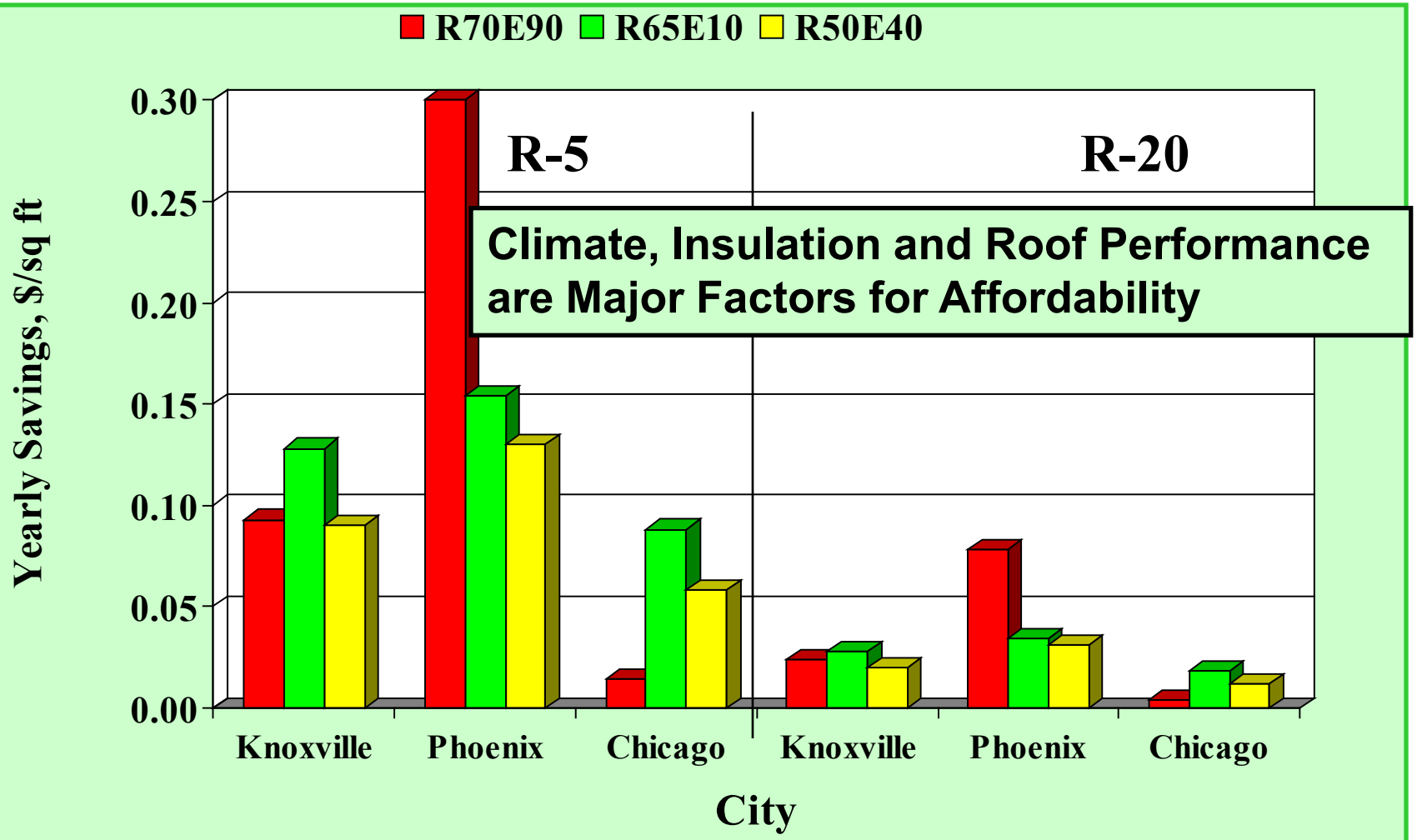
DOE/ORNL Conducting In-depth Air Barrier Research

- Sophisticated energy performance measurements
- Supports real world performance and code activity
- 20 wall panels with 13 manufacturing supplier partners and Syracuse Univ.
- Needed to support higher code levels leading to ZEB

DOE's Renewed Interest in Cool Roof Research and Implementation

- Secretary Chu's remarks promoting cool roofs
- Greater focus on code adoption
- Increased attention and budget for cool roof enabling research
  - Test protocols
  - Retrofit guide
  - **Enhanced cool roof energy performance calculator**
- International collaboration to promote cool roofs internationally where it can be the most cost effective

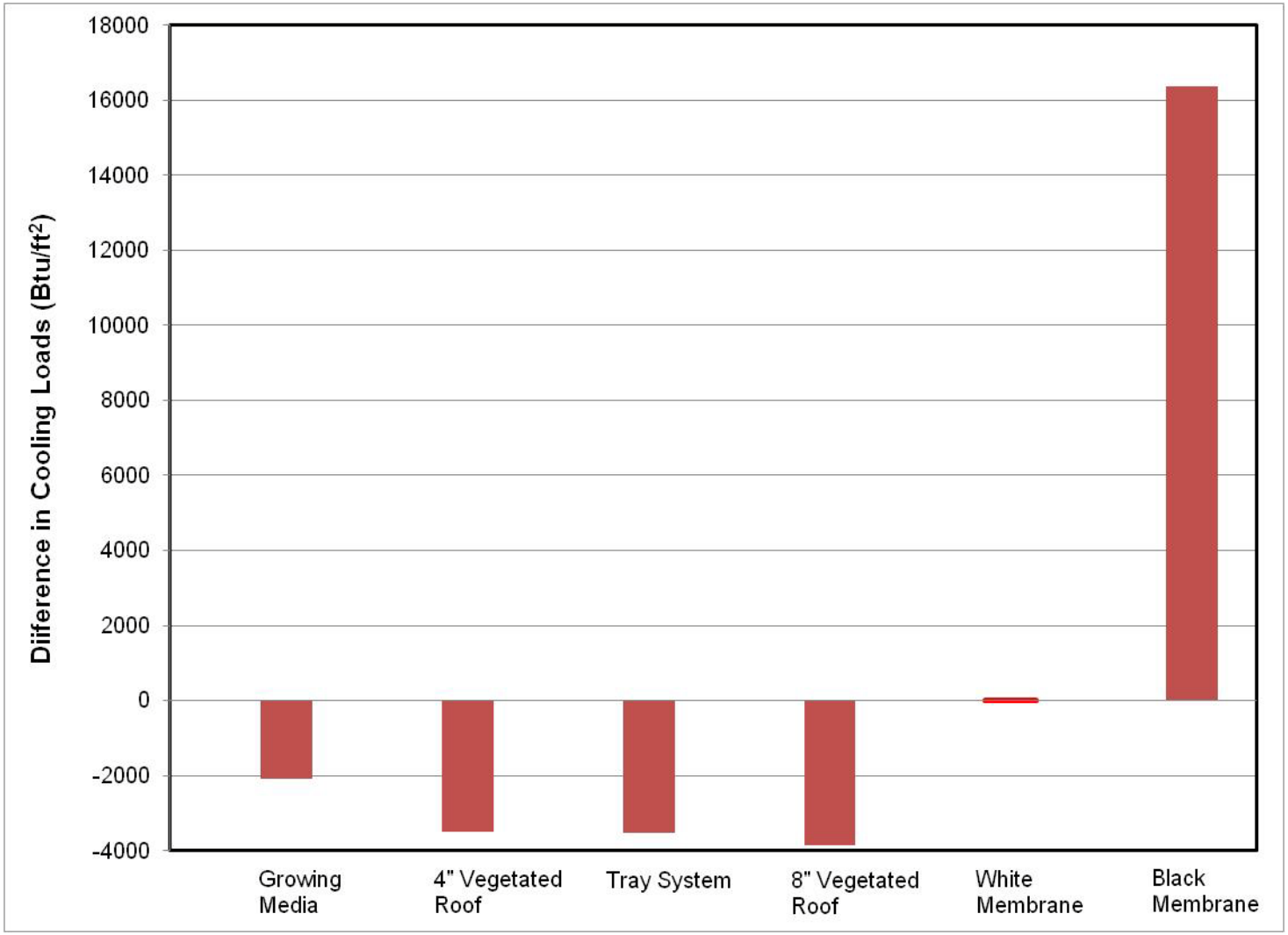
ROOF ENERGY SAVINGS



10 cents/kwh, COP of 2.0, Furnace AFUE 0.80, $1.30 Therm
NO PEAK DEMAND CREDIT – COULD DOUBLE SAVINGS

Garden Roofs Show Improved Performance - Preliminary Results

Comparison of Cooling Loads (Heat gain) Relative to White Control System



Aged Ratings are Important but Barriers for New Product Development

- CRRC “aged” values are essential but three years is long for innovative products
- Attempted to develop an accelerated protocol in the past but did not correlate with real world performance
- Initiating a comprehensive multi-year effort in FY10 with support from CEC, and will attempt to get world partners. LBNL will be the lead researcher with support from ORNL and in collaboration with Industry.
- Ultimate goal is to develop an ISO standard for world adoption

Most Recent Activities

- **Integrated Roof Calculator – ORNL and LBNL collaboration with support from CEC and DOE, coordination with EPA**
- US Domestic Retrofit Guide (Stakeholder Review – very soon)
  - Consideration of existing roof conditions
  - Technical options
  - Audience: Building owners and operators, Federal buildings, contractors
- Industry/Research Opportunity - Under ARRA funds, solicitations issued for advanced product development.
- World Opportunity Assessment
  - Identify existing programs
  - Identify potential partners for implementation (if funded in FY10, expected funding in FY11)
  - Internal draft complete, available for stakeholder review but not to be referenced

Carbon Mitigation/Community Savings – Where Application is not Cost Effective for Building Owner but may be for the Community

Cool Roof and Pavement Contributions to Mitigate Urban Heat Island

- Comprehensive Critical Review of Global Urban Heat Island Research – Initial Draft Available for Review (any day)
- Convene Scientific Panel to discuss, debate and develop research plan to validate macro global warming reduction potential through application of cool and cool-colored surfaces (roofs, walls, pavements) in urban areas of the world (Spring/Summer 2010)
- Nominations for competitive process to identify cool roof/global warming researchers welcome from all

International Implementation

- FY10 – Conduct analyses, establish partnerships, and initiate pilot activity if funding allows
- FY11 - Expect more comprehensive program
- APP – Asia Pacific Partnership on Clean Development and Climate (India, China, Australia, Japan, Korea, Canada, and US)
- APEC – Asia Pacific Economic Cooperation (21 Pacific Rim Countries, key areas South East Asia (Indonesia, Thailand, Malaysia, etc)
- Other areas of interest Middle East, Brazil, Africa
- Southern Europe – EU Cool Roof Rating Council recently established

Final Remarks

- The USA has initiated unprecedented investment in energy efficiency and renewable energy
- New technology will be essential to achieve zero energy buildings – major investment with Stimulus Funding
- Greater focus on international collaboration to promote efficient roofing systems
- Common question, how does cool roofs compare to PV: cool roofs are economic now and will be for along time in developing countries – PV is the future

Contact Information

P Marc LaFrance, CEM
Technology Development Manager
Building Technologies Program
Office of Energy Efficiency and Renewable Energy
US Department of Energy

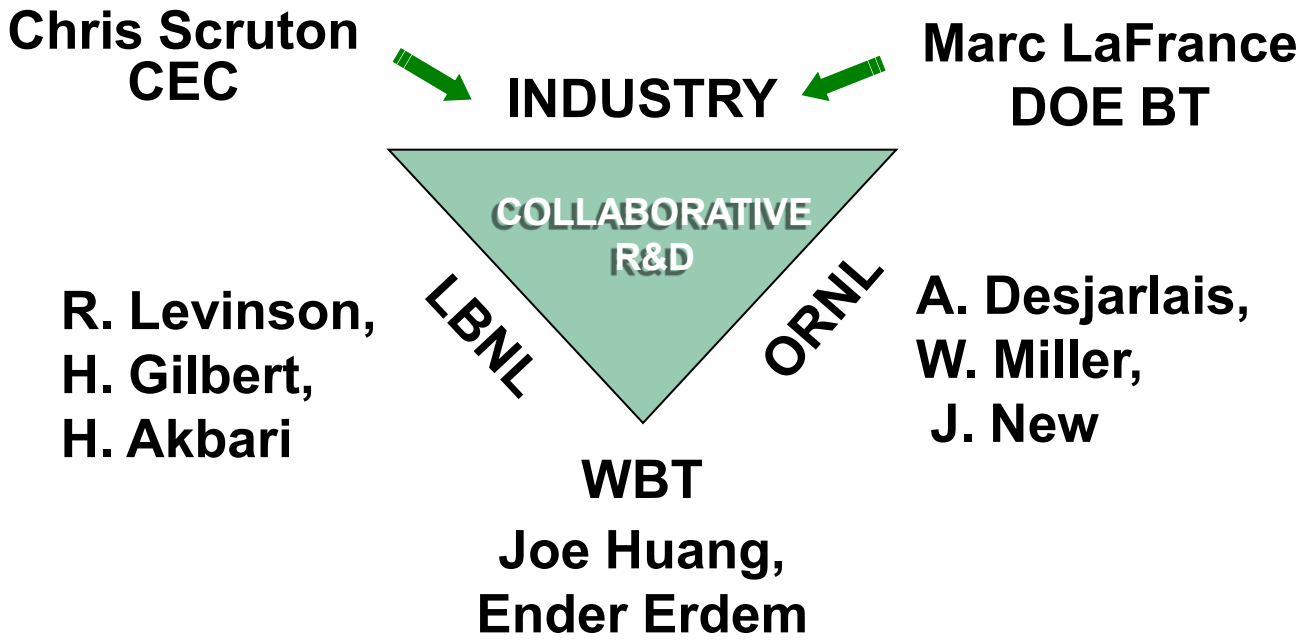
marc.lafrance@ee.doe.gov
1-202-586-9142
Fax 1-202-586-4617
www.eere.doe.gov

AtticSim Code

Presenter: William Miller, Ph.D.

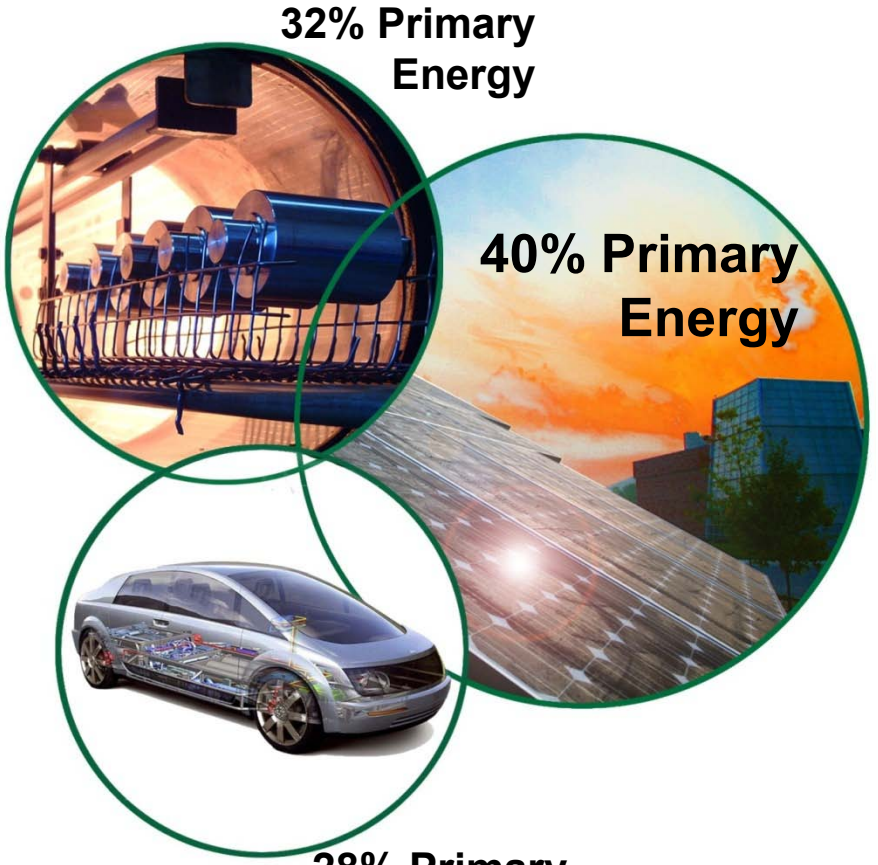
COMPUTER TOOL FOR SIMULATING COOL ROOFS

Roof Savings Calculator (RSC)



OBJECTIVE

Develop a web-based calculator with which consumers, contractors and distributors can estimate the cooling energy savings achieved by installing cool roofing on specific buildings



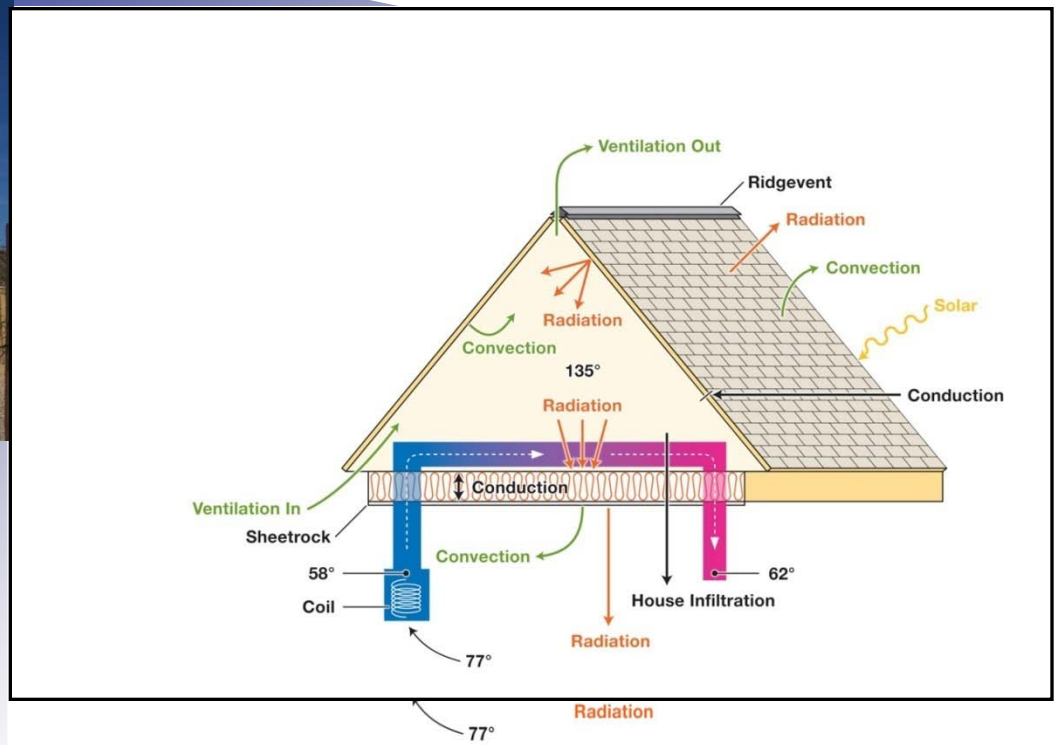
Goals for RSC

- Benchmark the measured energy savings for cool-colored roofing materials
- Educate consumers, contractors, engineers and architects
- Help manufacturers of cool-colored materials deploy their products
- Help utilities and public interest organizations refine incentive programs for cool roofs

AtticSim *(Attic Simulation)* Model

ASTM C 1340-99 Standard For Estimating Heat Gain or Loss Through Ceilings Under Attics

Roof & Attic Energy Balance



Petrie, T. W., K. E. Wilkes. 1998. "Effect of Radiant Barriers and Attic Ventilation on Residential Attics and Attic Duct Systems: New Tools for Measuring and Modeling," *ASHRAE Trans*., vol. 104, 1175-1192.

Miller et al. (2007), "Natural Convection Heat Transfer in Roofs with Above-Sheathing Ventilation." in Thermal Performance of the Exterior Envelopes of Buildings, X, proceedings of ASHRAE THERM X, Clearwater, FL., Dec. 2007.

Sequence of Surfaces Input to AtticSim for Modeling Roof and Attic

Surface index	Descriptors for interior and exterior surfaces N-S Ridge Orientation
1	attic floor
2	east facing roof or roof deck
3	west facing roof or roof deck
4	south facing gable
5	north facing gable
6	east facing eave wall
7	west facing eave wall
8	east facing elevated roof
9	west facing elevated roof

- Building materials: thermal conductivity, specific heat, and density permeance, and moisture storage properties
- Thermal emittance of all internal and external surfaces
- Solar absorptance of all exterior surfaces
- Geometry: inclination (roof pitch), orientation, footprint
- Attic ventilation scheme: soffit-to-soffit, soffit-to-ridge, soffit-to-gable
- Weather data

RP717 An Energy Calculation Model for Attics, Including Radiant Barriers

- AtticSim Benchmarked against test data from 7 different sources

					% Difference for Predicted and Measured Heat Flows	
Field Data	Attic Type	Attic R-Value	Attic Radiant barrier	# of Days for Summer	Summer AVG	Winter AVG
OCF	Gable Attic	R 38	No	3	5.5	-0.8
Ocala	Gable Attic	R 30			4.3	
	Gable Attic	R 19	Yes[1]		0.1	
Karns	Gable Roof	R 19	No	7	5.2	
TVA		R 30	No	2	-6.3	
		R 30	Yes[2]	2	11	

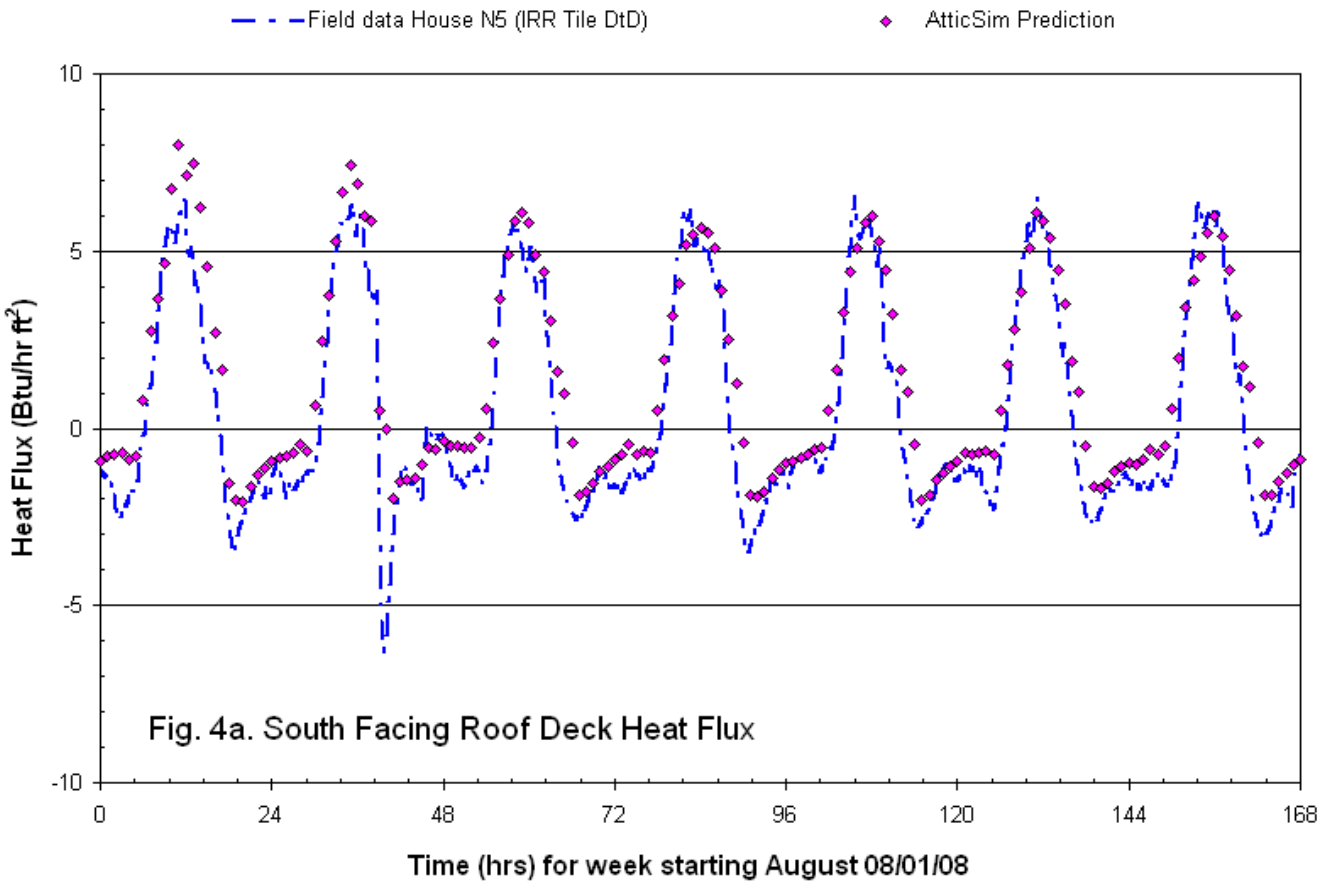
[1] Draped radiant barrier installed between roof rafters.

[2] Horizontal radiant barrier placed on top of attic floor insulation.

Owens Corning Fiberglass (OCF): Steady-state tests ASTM C976

Ocala,FL :Sponsored by Mineral Insulation Manufacturers Association

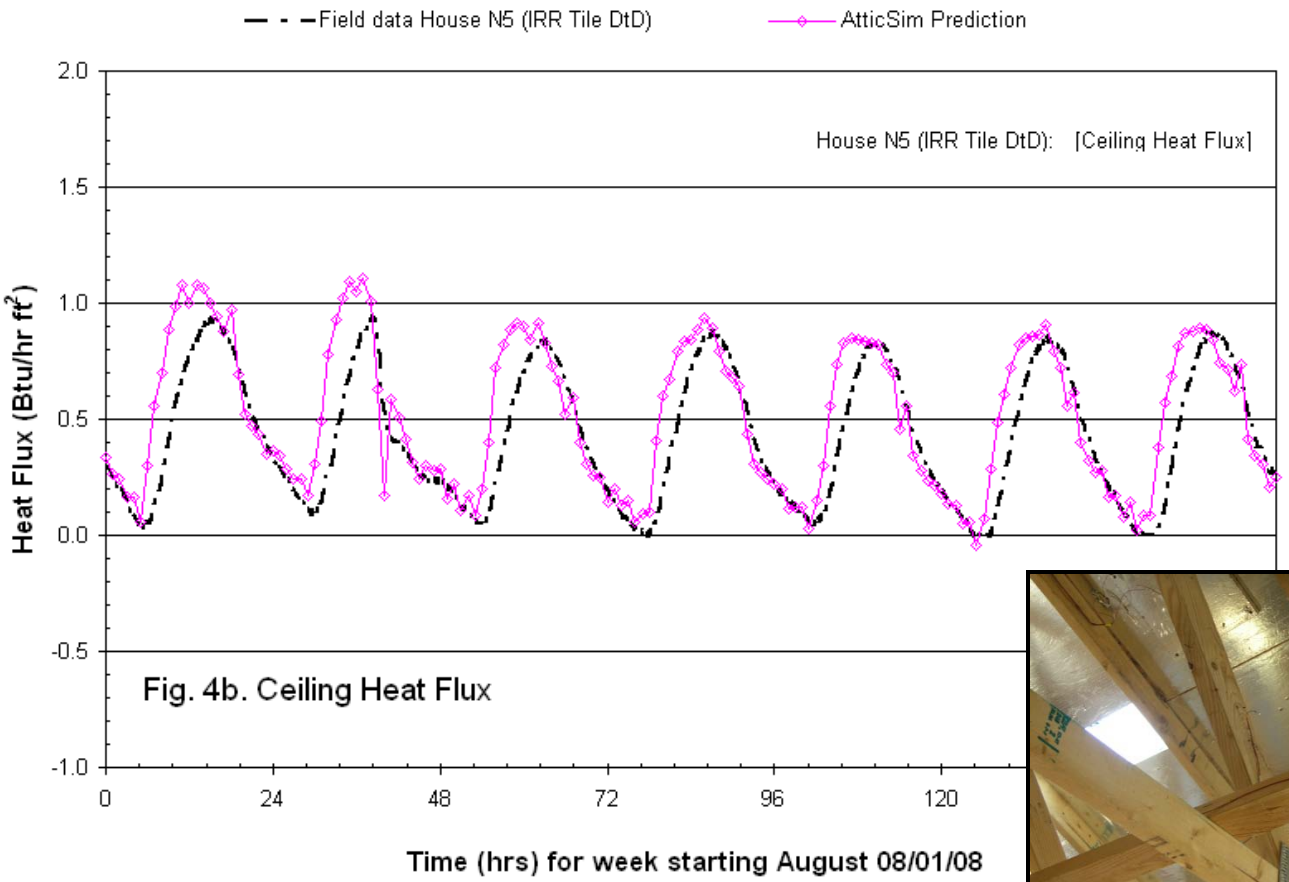
AtticSim Benchmark of Ft Irwin House (South-facing Roof Deck)



Cool Color Tile Direct-to-deck

Miller, W. 2010. Field experiments to evaluate cool-colored roofing. Task 2.5.7 CEC milestone report to be submitted to the Society of American Military Engineers.

AtticSim Benchmark of Ft Irwin House (Ceiling)



Cool Color Tile Direct-to-deck

Combining the capabilities of AtticSim and DOE-2.1E

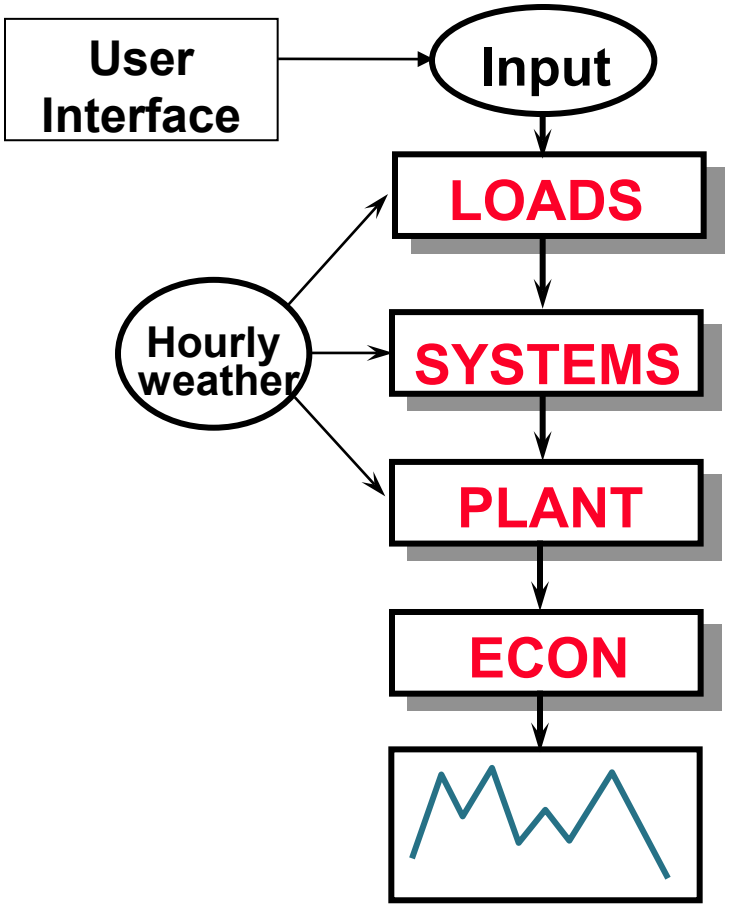
- To provide state-of-the-art modeling of the attic space including the ducts, ORNL's *AtticSim* program has been merged into *DOE-2.1E,* thus replacing the standard DOE-2 model for the attic.
- Modeling of the rest of the building and the HVAC system is left to *DOE-2.1E*.

DOE-2 Whole Building Code

Presenter:

Joe Huang
White Box Technologies

DOE-2.1E Whole Building Simulation Program



Building description

Heat gains and losses

Distribution of heating and cooling

Production of heating and cooling

Life-cycle cost analysis

Outputs — energy use and costs, indoor conditions, etc.

What is DOE-2 ?

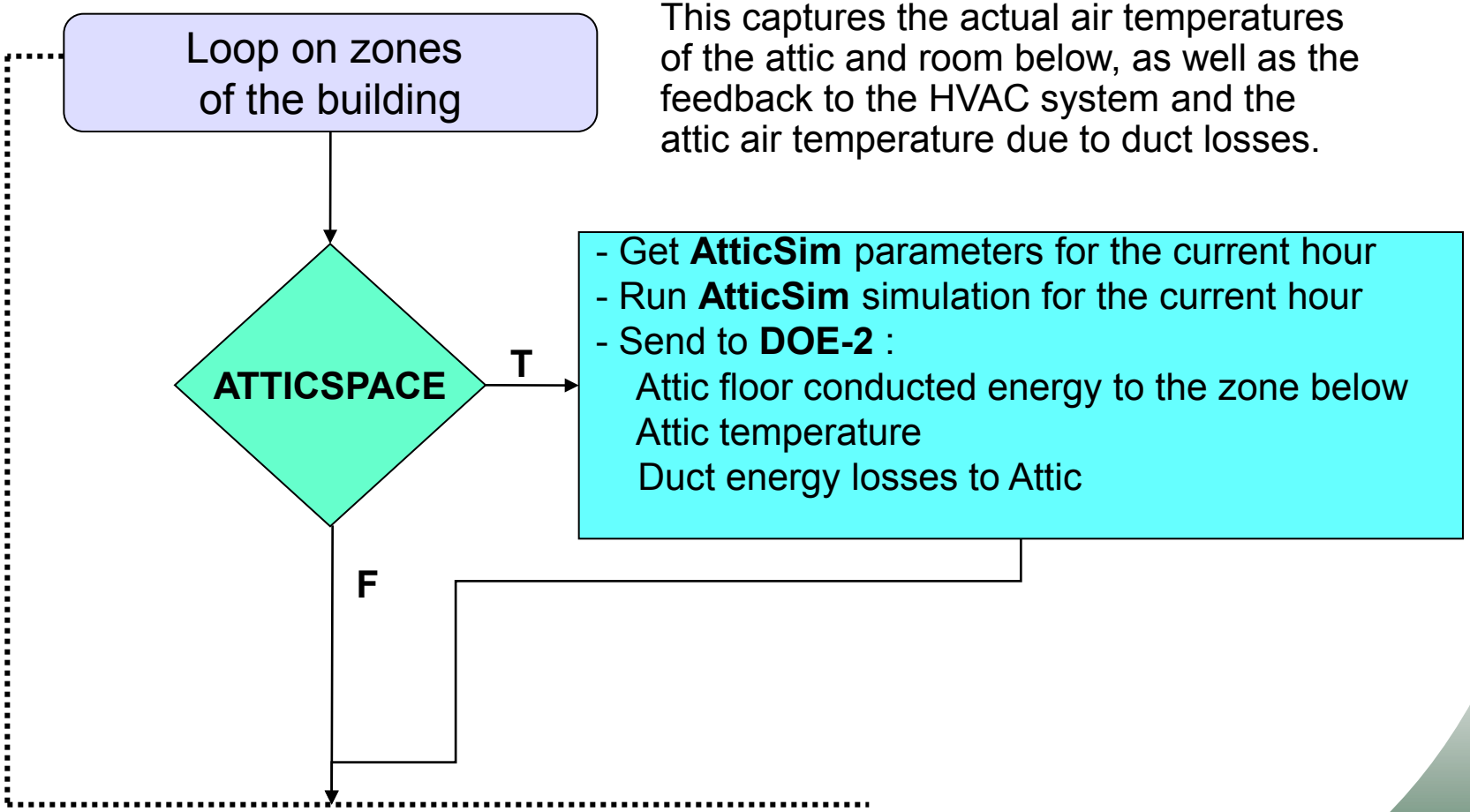
- unbiased well-documented public-domain computer program for building energy analysis
- developed by Lawrence Berkeley National Laboratory with support from U.S. Department of Energy
- last federally-supported version DOE-2.1E (1993), later version (DOE-2.2) supported by Southern Cal Edison
- Source code for DOE-2.1E can be procured, source code for DOE-2.2 is proprietary
- based primarily on ASHRAE procedures for calculating heat flows and building loads
- most widely used simulation program in the US and probably around the world
- easy-to-use user-interfaces available, e.g, eQUEST for DOE-2.2, VisualDOE or EnergyPro for DOE-2.1E

Harnessing DOE-2 in an easy-to-use Web-based Roofing Calculator

- DOE-2 is an engineering program that requires in-depth knowledge of how buildings are put together and operated and months of training.
- In its native form, DOE-2 uses a text-based input and output procedure that would take up to a week or more to develop, debug, and evaluate.
- The web-based roofing calculator greatly simplifies this process by using template files for which the user needs only to provide through the user-interface a few key building parameters, and more specific information on the building's attic and roof.
- The output from DOE-2 is handed back to the user-interface to be displayed on the screen.

Flow chart within DOE-2 SYSTEMS

Tight coupling between AtticSim and DOE-2.1E is achieved by running AtticSim during DOE-2's SYSTEMS simulation. This captures the actual air temperatures of the attic and room below, as well as the feedback to the HVAC system and the attic air temperature due to duct losses.

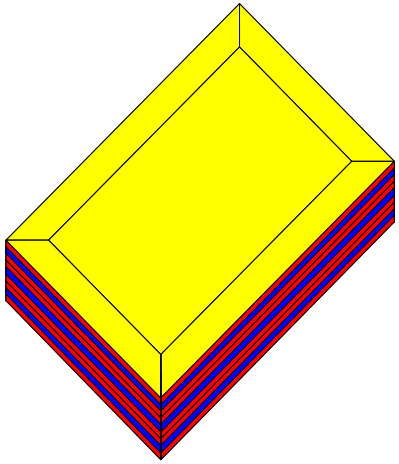


Roof types considered in the Roofing Calculator

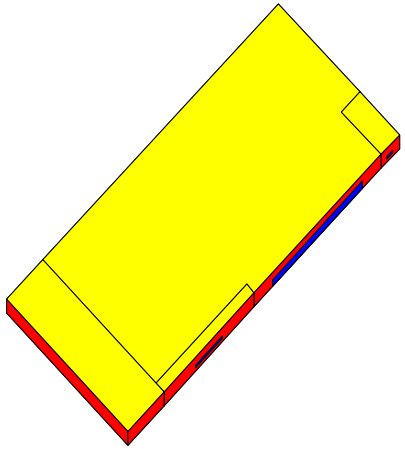
- Low-sloped roofs in three prototypical commercial building types
- Steep-sloped roofs in a prototypical residential and a prototypical commercial medium-sized office building

Low-sloped roofs in three prototypical commercial building types

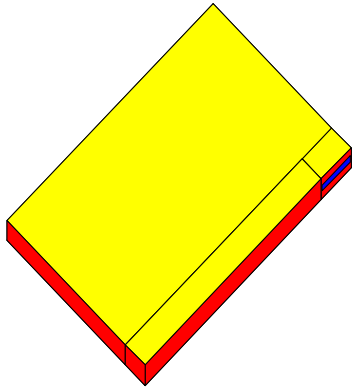
Medium Office



"Big Box" Retail



Warehouse



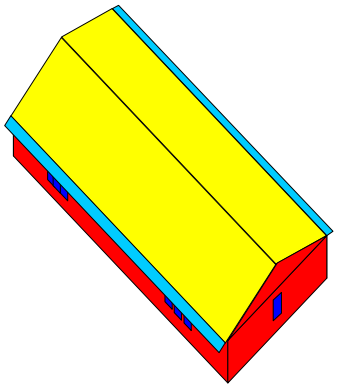
Torcellini et al. 2008, "DOE Commercial Building Benchmark Models", NREL/CP-550-43291, National Renewable Energy Laboratory, Golden CO.

Building and roof conditions modeled for buildings with low-sloped roofs

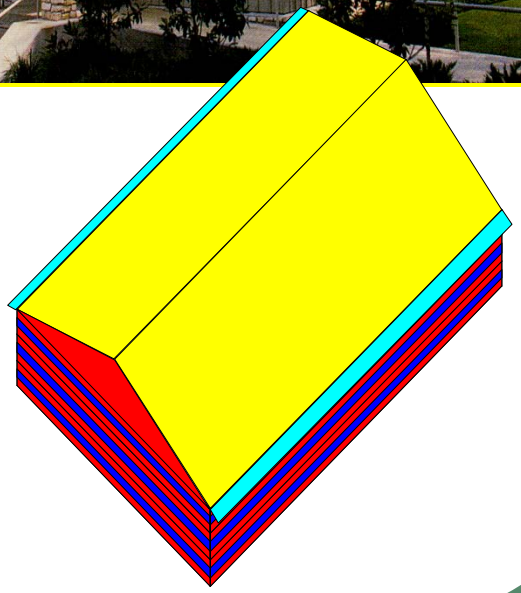
- Three building types (office, box store, warehouse)
- Four roof systems (single-ply, concrete paver, bitumen, built-up roof)
- Three vintages of building and HVAC system (pre-1980, 1980 – 1990, post-1990)
- Two types of heating (gas or oil furnace, electric heat pump); air-conditioning assumed
- Nine levels of roofing/ceiling insulation (R0, R3, R5, R7, R11, R19, R38, R50, other)
- Seven levels of roof solar reflectance (0.10, 0.20, …, other)
- Six levels of roof thermal emittance (0.15, 0.20, 0.50, 0.85, 0.90, other)
- Simulations outputs: annual and monthly heating and cooling energy usage

Steep-sloped roofs in prototypical residential and commercial buildings

1- or 2-story Residential



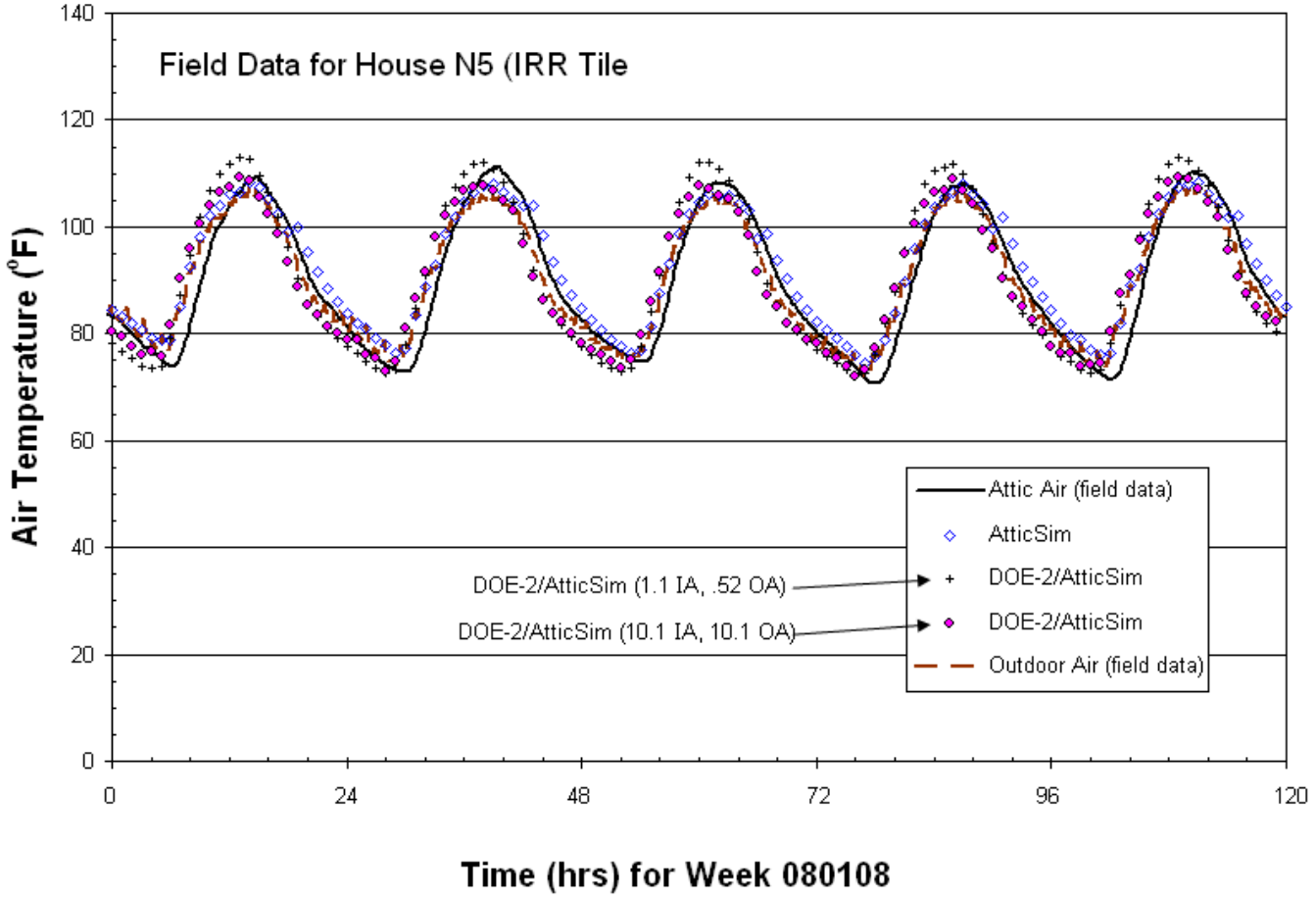
Medium Office



Building and roof conditions modeled for buildings with steep-sloped roofs

- Two building types (residential and office)
- Three levels of roof thermal mass (tile, metal, asphalt shingle)
- Two duct location cases (attic, conditioned space)
- Two choices for radiant barrier (yes, no)
- Two choices for above-sheathing ventilation (yes, no)
- Three vintages of building and HVAC system (pre-1980, 1980 – 1990, post-1990)
- Nine levels of roofing/ceiling insulation (R0, R3, R5, R7, R11, R19, R38, R50, other)
- Seven levels of roof solar reflectance (0.10, 0.20, …, other)
- Six levels of roof thermal emittance (0.15, 0.20, 0.50, 0.85, 0.90, other)
- Simulations outputs: annual and monthly heating and cooling energy usage

AtticSim and DOE-2.1E/AtticSim Benchmark of Ft Irwin House "Attic Air Temperature"



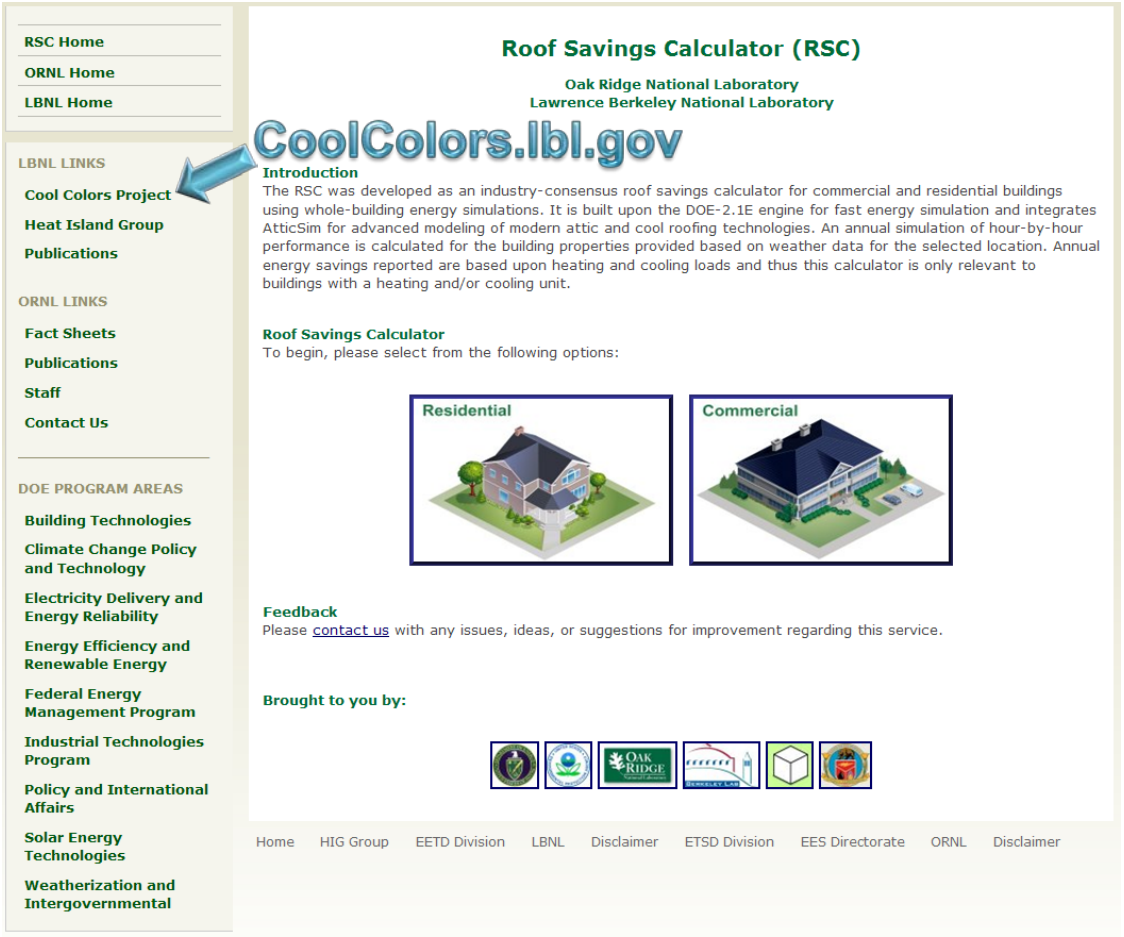
Cool Color Tile Direct-to-deck

Roof Savings Calculator

Presenter: Joshua New

Roof Savings Calculator
DOE-2.1E+AtticSim

- **Building Details**
- **HVAC efficiency and utility pricing**
- **Roof and Attic Information (base vs. comparison)**
- **Reports energy and cost savings**



Roof Savings Calculator

- **Replaces:**
  - EPA Roof Comparison Calc
  - DOE Cool Roof Calculator

- **Minimal questions (<20)**
  - Only location is required
  - Building America defaults
  - Help links for unknown information

Calculator Input Comparison Chart

	RSC[1]	PAC Slides[2]	PAC QRpt[3]	EPA[4]	DOE[5]
Building Type	✓	✓	✓	✓	
Location	✓	✓		✓	✓
Days of Operation per week		✓	✓	✓	
Building stock	✓	✓		✓	
Cooling system efficiency (SEER)	✓	✓	✓	✓	✓
Type of heating	✓	✓	✓	✓	✓
Heating system efficiency	✓	✓	✓	✓	✓
Duct location	✓	✓	✓		
Level of roof/ceiling insulation	✓	✓	✓	✓	✓
Above-sheathing ventilation	✓	✓			
Radiant barrier	✓	✓			
Roof thermal mass	✓	✓			
Roof solar reflectance	✓	✓	✓	✓	✓
Roof solar reflectance (black compare)	✓		✓	✓	
Roof thermal emittance	✓	✓	✓		✓
Roof thermal emittance (black compare)	✓		✓		
Internal load		✓			
Conditioned space under roof		✓			
Gas and electricity costs	✓	✓	✓	✓	✓
Inclination / Roof Area	✓			✓	
HVAC Schedule			✓		
Conditioned space (ft^2)	✓			✓	
Number of floors	✓				
Window-to-wall ratio	✓				

[1] Current version of the "Roof Savings Calculator" (RSC) as of 1/11/10
[2] Based on March 6, 2008 Project Advisory Committee Meeting (PAC_Inputs.ppt).
[3] Based on January 21, 2009 Project Advisory Committee Quarterly Report (Qrpt-08Q4.pdf).
[4] Based on http://www.roofcalc.com/RoofCalcBuildingInput.aspx
[5] Based on http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm

Roof Savings Calculator

- Dynamic web technologies:
  - DHTML (Dynamic HyperText Markup Language)
  - AJAX (Asynchronous Javascript and eXtensible Markup Language)
  - CSS (Cascading Style Sheets)
  - PHP (Personal Home Page language)
  - jQueryUI (Javascript libraries)

- Interface design principles:
  - Common phrasing
  - Answer order
  - Radio buttons (Fitts' Law)
  - George Miller's Law (7±2)
    - ClANSAFBIDODIRSDOE

Roof Savings Calculator

DEMO

Presenter: Joshua New

Roof Savings Calculator

Phase II Initiatives:

- Queuing system
- Mouseover tooltips
- Pricing models
- Schedule/usage profiles
- Internal temperatures (3rd world countries)
- Additional building types
- Ductwork above the roof plane
- Advanced mode options
- Open-source interest

Thank you for your time!

QUESTIONS??

This Concludes the Cool Roof Webinar

Some Publications

Miller, W., J. New, A. Desjarlais, Y.J. Huang, E. Erdem, R. Levinson and H. Akbari. 2010. Development of an energy savings calculator. Task 2.5.4 milestone report to be submitted to the RCI Building Envelope Technology Symposium, San Antonio, TX, November 2010.

Miller, W. A., Keyhani, M., Stovall, T. and Youngquist, A. 2007. “Natural Convection Heat Transfer in Roofs with Above-Sheathing Ventilation,” in Thermal Performance of the Exterior Envelopes of Buildings, X, proceedings of ASHRAE THERM X, Clearwater, FL., Dec. 2007.

Petrie, T. W., K. E. Wilkes. 1998. “Effect of Radiant Barriers and Attic Ventilation on Residential Attics and Attic Duct Systems: New Tools for Measuring and Modeling,” *ASHRAE Trans*., vol. 104, 1175-1192.

D. Ober and Wilkes, K. 1997. An Energy Calculation Method for Attics, Including Radiant Barriers, ASHRAE Research project RP 717, 1997.

Torcellini, P., M. Deru, B. Griffith, K. Benne, ,M. Halverson, and D. Winiarski. 2008., “DOE Commercial Building Benchmark Models”,NREL/CP-550-43291, National Renewable Energy Laboratory, Golden CO.

Thank you for attending the Webinar

Calculating Energy Savings of Cool Roofs

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